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THERMAL RESPONSE IN 'MACACA MULATTA' EXPOSED TO 15- AND 20-MHZ --ETC(U)
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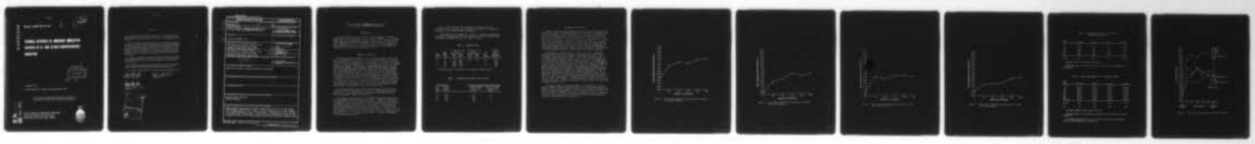

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THERMAL RESPONSE IN *MACACA MULATTA* EXPOSED TO 15- AND 20-MHZ RADIOFREQUENCY RADIATION

September 1977

Interim Report for Period January-December 1976

Approved for public release; distribution unlimited.

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This interim report was submitted by personnel of the Radiation Physics Branch, Radiation Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 7757-01-43.

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The animals involved in this study were maintained and used in accordance with the Animal Welfare Act of 1970 and the "Guide for the Care and Use of Laboratory Animals" prepared by the National Academy of Sciences-National Research Council.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

JEROME H. KRUPP, D.V.M.
Project Scientist

JOHN C. MITCHELL, B.S.
Supervisor

ROBERT G. MCIVER
Brigadier General, USAF, MC
Commander

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Rhesus monkeys were exposed to high incident-power levels of 15- and 20-MHz radiofrequency radiation for 3 hours. After a modest rise in rectal temperature, thermoregulatory control was established. Temperature rise was related to frequency and incident power. Equivalent power absorptions in man at these frequencies would be 15-25 times greater than current personnel exposure limits.

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THERMAL RESPONSE IN *MACACA MULATTA* EXPOSED TO 15- AND 20-MHZ RADIOFREQUENCY RADIATION

INTRODUCTION

Previous exposures of rhesus monkeys (*Macaca mulatta*) to 26-MHz radiofrequency (RF) radiation at incident power levels up to 1000 mW/cm^2 showed that the absorbed power produced a modest rectal temperature rise with compensatory thermoregulation which was maintained for the entire 6-hour exposure period (1). To further explore the high-frequency (HF) band, additional animals were similarly exposed to 15- and 20-MHz RF radiation at each of two different power levels.

METHODS AND MATERIALS

Ten rhesus monkeys, weighing 3.5 ± 0.5 kg, were housed in the vivarium, fed a commercial ration twice daily, and allowed water ad libitum. Each morning of the experiment, they were placed in slotted plastic cages, 20 x 20 x 40 cm, and transported to the RF-radiation facility. Following a short rest period, rectal and skin temperatures were taken, then two animals were placed in a rectangular coaxial HF-band transmission line (5). The remaining animals were kept adjacent to the exposure chamber, but outside the radiation field. Every half-hour rectal temperatures were recorded from each animal; the radiation was off for approximately 2 minutes at this time. The exposures continued for a total of 3 hours. Temperatures of all animals were recorded immediately after termination of exposure, and for the exposed pair, one additional recording was made 10 minutes post exposure. Two exposure periods were done each day until all animals had been exposed to one combination of frequency and power. This procedure was repeated until all animals had been exposed to four combinations, two frequencies at two power levels each.

Rectal temperatures were recorded using thermistor probes (Yellow Springs Instrument Telethermometer Model 73). Temperatures were estimated ±0.1° C. The thermistor was calibrated with an NBS-certified mercury thermometer (Taylor Instrument Co.).

All exposures were obtained in the HF-band TEM-mode exposure device, with two animals being exposed simultaneously. Power was supplied to the exposure device by an AN/FRT-6B transmitter operating in the continuous-wave (CW) mode and was maintained at the desired input power ±4%. The 20-MHz exposures were made using input powers of 40 and 24 kW (CW), and the 15-MHz exposures were made with input powers of 40 and 29 kW. The E-fields were vertical, and animals were exposed in the erect position (E-polarization). Animals were exposed above the center conductor on the lateral center line: one animal 50 cm forward of and one 50 cm behind the longitudinal center line.

The E- and H-field maps of the cage were uniform within ±2%. Measurements were obtained with calibrated 10-cm dipole and loop antennas read out on a Kiethley 600B electrometer.

Field dimensions are summarized in Table 1. Comparative values for man exposed to these conditions were obtained from the USAFSAM RF Radiation Dosimetry Handbook (3) and are shown in Table 2.

TABLE 1. DOSIMETRY DATA

Freq. (MHz)	Input power (kW)	Average E-Field (V/m) Front cage	Average E-Field (V/m) Rear cage	Average H-Field (A/m) Front cage	Average H-Field (A/m) Rear cage	E/H ratio (ohms)	Incident power density[a] (mW/cm^2)
20	40	2220	2160	4.85	4.75	450	1270
	24	1710	1680				760
15	40	2020	1915			375	1025
	29	1750	1670				775

[a]Calculated from E-field data and averaged for cage position.

TABLE 2. COMPARATIVE EXPOSURE VALUES FOR MAN

Primate Data: Exp. freq. (MHz)	Primate Data: Incident power (mW/cm^2)	For Equivalent Absorbed Power in Man: Incident power at same freq. (mW/cm^2)	For Equivalent Absorbed Power in Man: Freq. for same incident power (MHz)
20	1270	225	8
20	760	150	8
15	1025	205	5
15	775	155	5

RESULTS AND DISCUSSION

Figures 1-4 show the mean rectal temperature differences for the four exposure conditions. Mean temperature differences and the standard errors are shown in Table 3. The differences were obtained by subtracting the mean of control temperatures for a given condition from the mean of exposed animals (Table 4). For each animal, control temperature means were derived from the control values that corresponded to his exposure time of day, thus eliminating the significant time-of-day effect which existed. Figure 5 shows the means of Table 4 for exposed animals through the full 190-minute observation period. Figure 6 gives the maximum temperature rise that occurred during the 3-hour period of exposure for the conditions of this experiment, together with data from previous work at 26 MHz.

The differences (exposed-control) show that all four irradiation conditions had a significant change in temperature over time ($P<.001$). In general, temperatures rose quickly in the first 30 minutes, then leveled off and fluctuated slightly or continued a slow rise for a time as thermoregulatory mechanisms were brought into play. By comparing all four conditions with regard to trend in temperature rise, some frequency X time interaction was indicated ($P<.08$). There is a suggestion that the higher frequency increases the body temperature more during the first hour and then maintains the higher level throughout the exposure period. This would conform to the concept of a thermal burden based on absorbed power (4), which has been shown to be frequency dependent (2). The homeostatic-temperature-control ability of the animals to adjust to the stress at levels 15 to 25 times greater than current permissible exposure levels for man, lends support to standards which are based in part on thermal burden and frequency. Following cessation of radiation, there was a significant drop in temperature within 10 minutes except for the 15 MHz/775 mW/cm^2 group ($P<.05$).

In summary, exposure of rhesus monkeys to RF radiation in the HF range, at power levels approximating 15-25 times the maximum permissible exposure limits for man, results in a modest rise in body core temperature which is adequately compensated for over an extended period of time, i.e., 3 hours or more. The rectal temperature response is related to frequency and field strength and conforms to generally accepted views regarding frequency, power absorption, and body size.

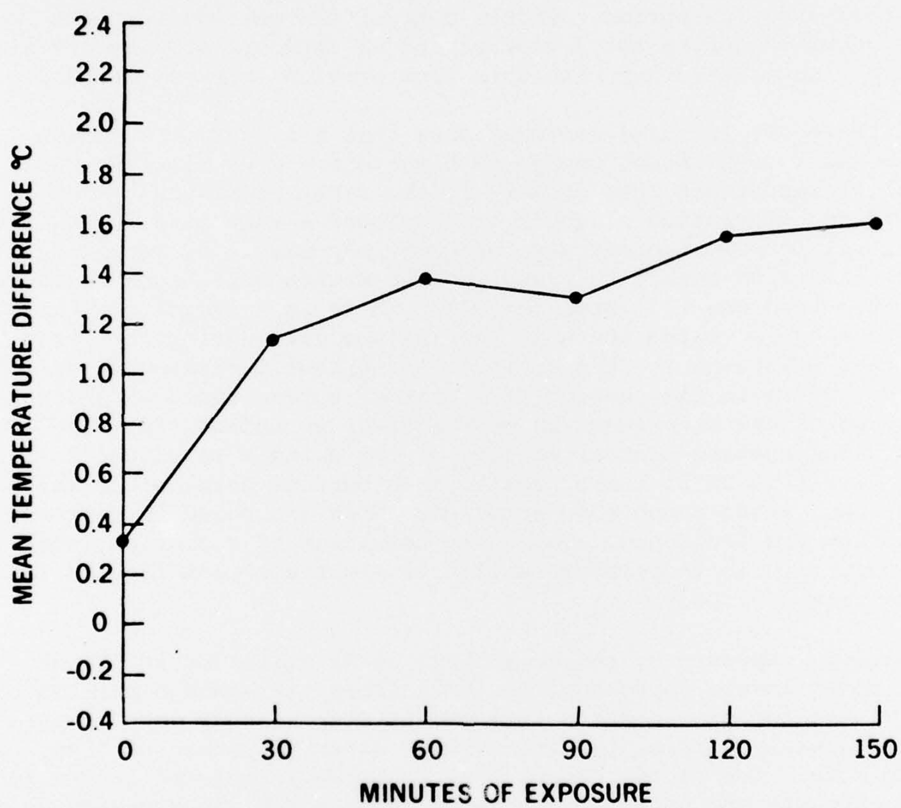

Figure 1. Mean rectal temperature differences for 20 MHz, 1270 mW/cm^2 exposure.

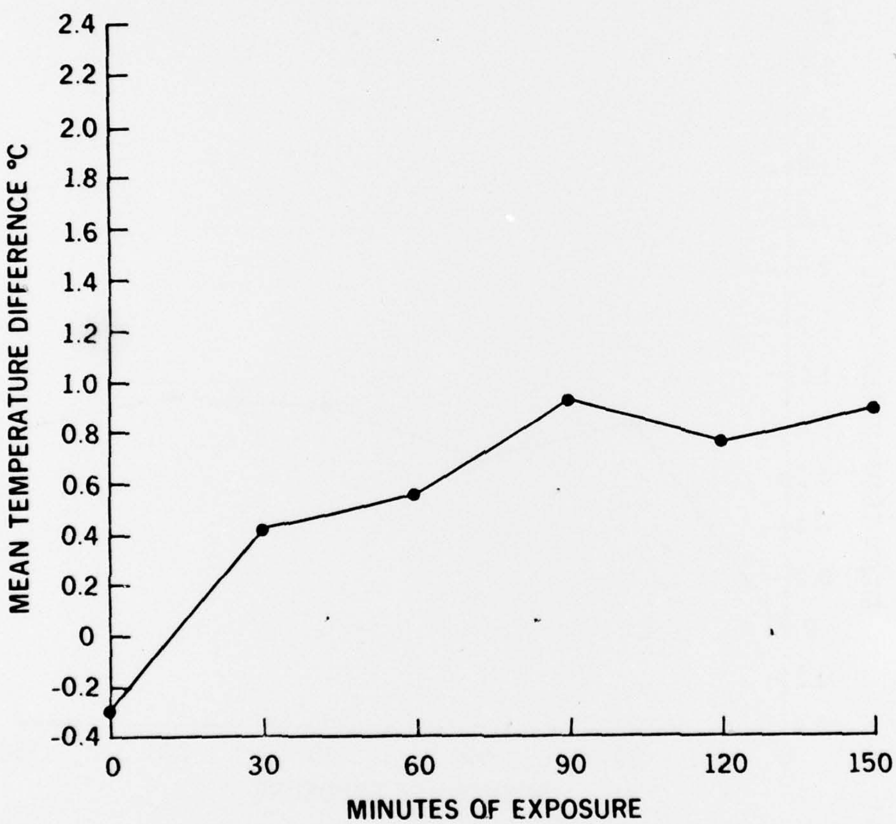

Figure 2. Mean rectal temperature differences for 20 MHz, 760 mW/cm^2 exposure.

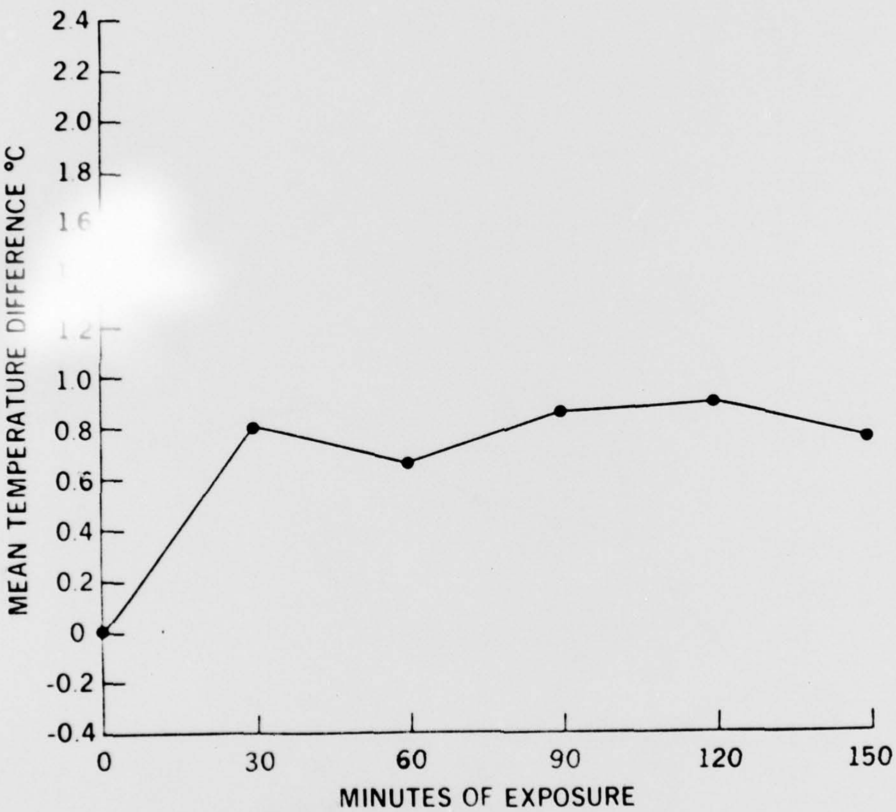

Figure 3. Mean rectal temperature differences for 15 MHz, 1025 mW/cm^2 exposure.

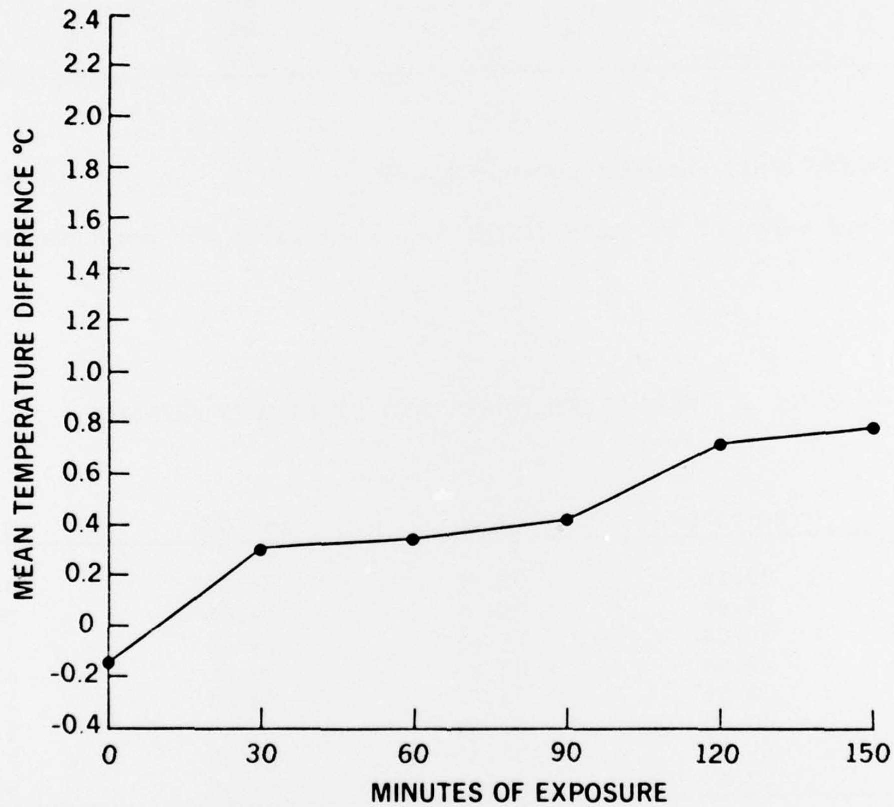

Figure 4. Mean rectal temperature differences for 15 MHz, 775 mW/cm^2 exposure.

Table 3. MEAN TEMPERATURE (^{o}C) DIFFERENCES
(Irradiated - Control)

Time (min)	20/1270[a]	20/760	15/1025	15/775
0	.36	-.30	-.01	-.15
30	1.13	.42	.81	.29
60	1.38	.56	.65	.34
90	1.30	.92	.85	.41
120	1.57	.76	.88	.71
150	1.60	.88	.75	.79
SE(D)[b]	.215	.162	.141	.164

[a]Frequency (MHz)/incident power (mW/cm^2).

[b]Standard error of the mean difference. Not valid for comparing two differences.

TABLE 4. MEAN TEMPERATURES (^{o}C) OF EXPOSED PRIMATES

Time (min)	20/1270[a]	20/760	15/1025	15/775
0	39.18	38.46	38.75	38.56
30	39.91	39.16	39.55	38.98
60	40.04	39.28	39.37	39.01
90	39.94	39.58	39.51	39.01
120	40.15	39.32	39.44	39.20
150	40.15	39.43	39.30	39.27
180	39.95	39.46	39.25	39.06
Post 10	39.31	39.07	39.05	38.93
SE(D)[b]	.203	.144	.083	.129
SE[c]	.170	.104	.036	.065

[a]Frequency (MHz)/incident power (mW/cm^2).

[b]Standard error of the difference between two time means for the same radiation.

[c]Calculated standard errors of the difference between 180 exposure minutes and 10 minutes post irradiation.

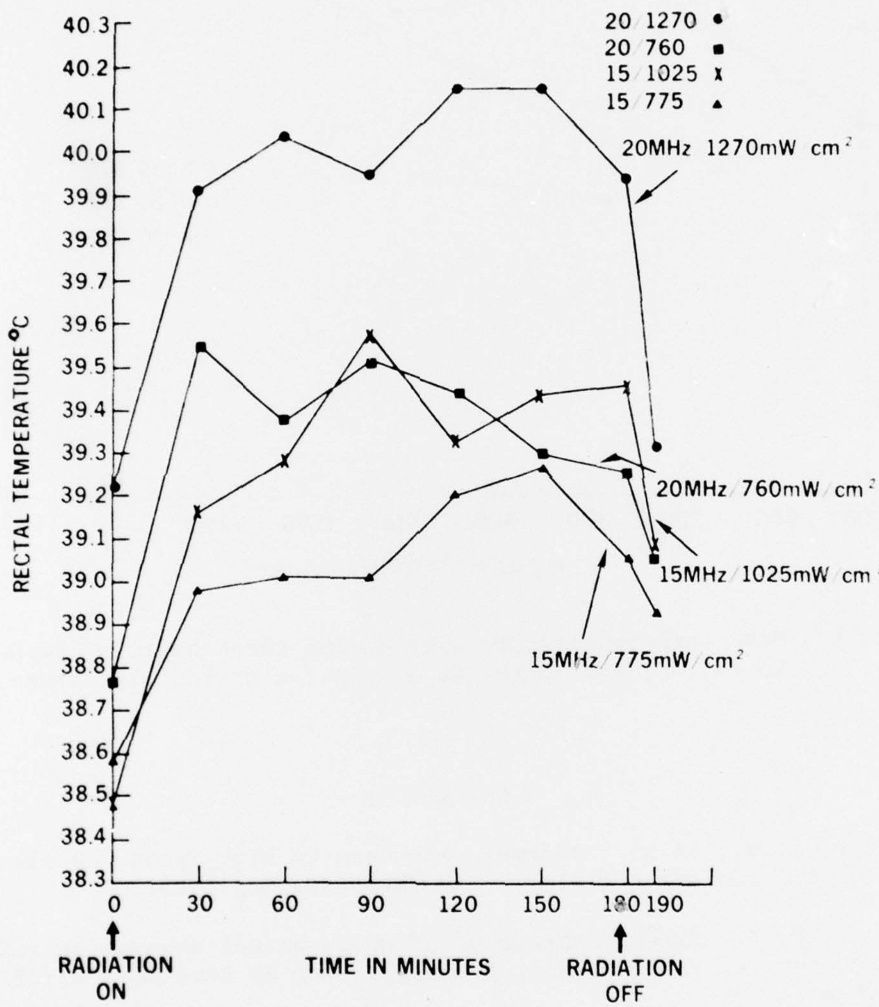

Figure 5. Mean rectal temperatures, all exposed animals.

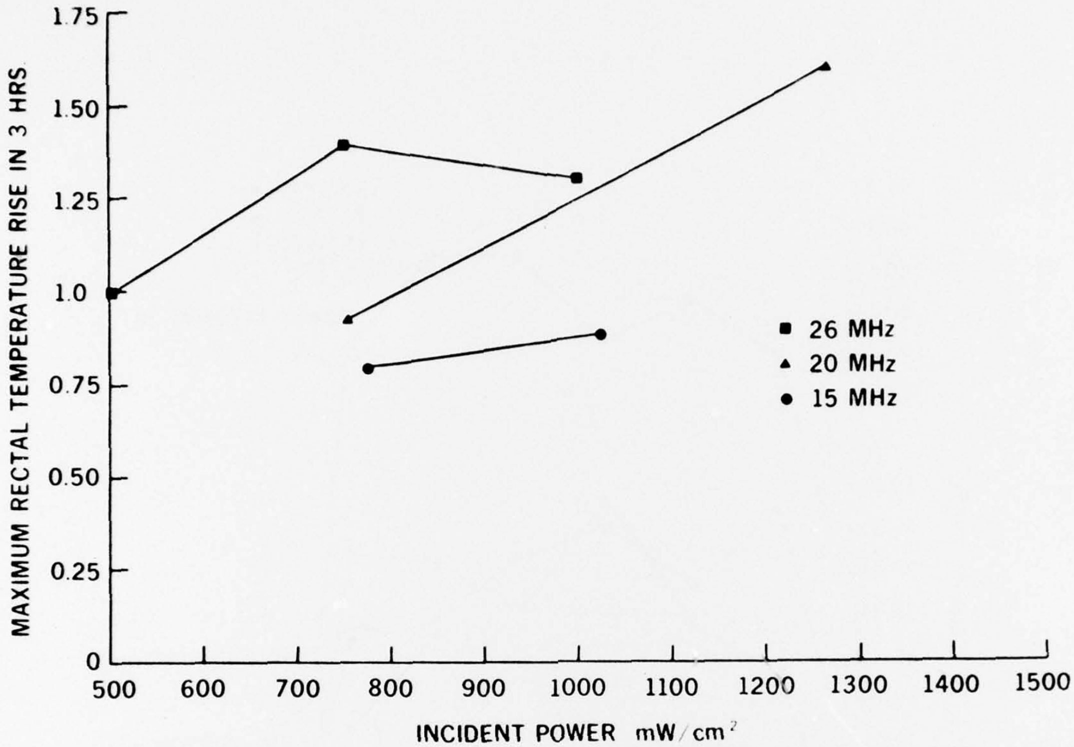

Figure 6. Mean core temperature rise during three hours of exposures to 26, 20, and 15 MHz as a function of incident power.

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